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Prognostic Effect of Optic Nerve Sheath Diameter Measurement in Traumatic Brain Injury Patients Admitted to Emergency Department

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Abstract

Emergency specialists (ESs) are at the forefront of the scene against secondary injury following traumatic brain injury (TBI). In this sense, management strategies used in the emergency department are very important, particularly those taking the Glasgow coma scale (GCS) score as a reference. Patients with neurological injury are at particular risk of intracranial pressure (ICP) increase, which, unless treated appropriately, leads to secondary brain injury that is associated with worse outcomes among patients suffering TBI. Optic nerve sheath diameter (ONSD) monitoring is a novel method that has gained widespread interest in the emergency medicine society in recent years. Evaluation of ONSD has been used as an alternative tool to determine elevated ICP since the former is directly proportional to intracranial pressure increase. Detecting a raised ICP with ONSD, to determine the prognosis of patients with TBI, and to determine its relationship with other non-invasive, simple tools with a reasonable level of diagnostic accuracy are of great importance, especially for emergency department (ED) physicians working with a great burden of overcrowded ED.

Keywords: *traumatic brain injury, emergency department, optic nerve sheath diameter, prognosis*

List of Abbreviations

CNS: central nervous system

CSF: cerebrospinal fluid

CT: computed tomography

ED: emergency department

ES: emergency specialist

GCS: Glasgow coma scale

ICP: Intracranial pressure

MRI: magnetic resonance imaging

US: ultrasonography

TBI: Traumatic brain injury

Introduction

Patients with traumatic brain injury, one of the most common causes of mortality and morbidity around the world, usually first seek help in the EDs. Patients with neurological injury are at particular risk of ICP increase, which, unless treated appropriately, leads to secondary brain injury that is associated with worse outcomes among patients suffering TBI (Sekhon et al., 2014; Sonmez et al., 2019). Although patients with neurotrauma are typically monitored by recording neurological vital signs, this task is not simple in overcrowded EDs and necessitates the introduction of easy-to-use, non-invasive tools to accomplish that goal. ONSD monitoring is a novel method that has gained widespread interest in the emergency medicine society in recent years. ONSD is measured by brain computed tomography (CT) or ocular ultrasonography (US); by indicating elevated ICP, it provides information about the prognosis of patients suffering TBI (Lee, Kim, & Yun, 2020).

Optic Nerve Sheath

As a part of the central nervous system, the optic nerve protrudes into the orbita in the process of embryogenesis, with the three layers of the meninges forming its sheath. Importantly, during the same time, there occurs a free passage of the cerebrospinal fluid (CSF) into the subarachnoid spaces in the cranium and the orbita, equilibrating both subarachnoid pressures and allowing the reflection of any increase in ICP or CSF to ONSD, causing the dilation of the latter (Gokcen et al., 2017; Komut et al., 2016).

Measurement of ONSD

Brain CT or ocular US can be used to measure ONSD. The majority of color ultrasound systems using high-frequency linear probes (7.5 MHz or higher) with a lateral spatial resolution below 0.4 mm are able to perform ultrasonography of ONSD and the optic nerve. The examination is performed with the examiner positioned at the head of the examination table and the patient lying in the supine position; to prevent pressure on the eye, the patient's head and upper body should be positioned at 20–30° relative to the examination table. Data recording takes a minimum of 1 minute while the patient holds his/her position described above. Following the application of a good amount of gel to the closed upper eyelid, the transducer is put on the lateral aspect of the orbit. The patient is required to look forward with the eyes closed in order to immobilize the eyeballs and to distinguish the major anatomical landmarks (optic nerve and lens) better and visualize the optic nerve together with the globe and lens. The globe is visualized as a homogenously anechoic structure. The lens, by forming a hyperechoic line, divides the globe into anterior and posterior compartments. The optic nerve lies posterior to the globe in the axial plane. The optic nerve and its sheath can be identified by setting the brightness and contrast to optimal settings. As the optic nerves have a well-demarcated border and a longitudinal compact structure, ONSD measurement needs to be done with an electronic caliper, from a point that is 3 mm behind the globe, and in a perpendicular fashion to the optic nerve axis. Three measurements should be averaged to minimize intra-observer variability (Fig. 1) (Lochner et al., 2019). Literature studies using intensive care and emergency point of care ultrasonography measure the ONSD diameter from the inner edges of the two opposite points of the ONS and accept an upper limit of normal of up to 4 mm in infants, 4.5 mm in children, and 5 mm in adults; consequently, values bilaterally exceeding 5 mm are indicative of ICP levels above 20 mmHg (Hylkema, 2016).

ONSD is quantified 3 mm behind the eyeball, just below the sclera using CT; typically, transverse diameter is measured from the coronal plane, with the optic nerve being perpendicular to sagittal and axial planes (Fig. 2) (Sonmez et al., 2019).

Fig1. *Transverse measurement of optic nerve 3 mm proximal from optic disk while eyelids were closed.*

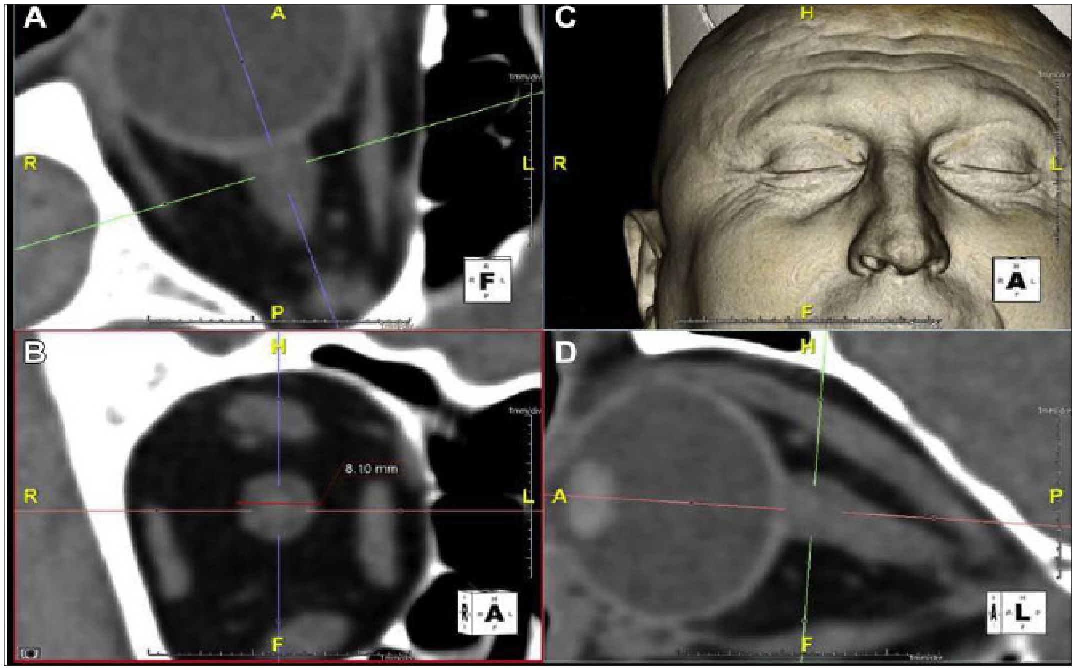

Fig2. *Coronal plane (B) perpendicular to both transvers (A) and sagital planes (D) of the optic nerve. In the coronal plane the transverse diameter of ONS was measured.*

Effect of ONSD on Prognosis

After TBI, cerebral edema (increased amount of water inside the cells or interstitium of the central nervous system (CNS) and associated intracranial pressure increase are the already known major contributors to poor prognosis. In severe TBI, it is aimed to prevent secondary injury (Benjamin E. Zusman, 2020; Dixon et al., 2020). It is recommended by the Guidelines for the Management of Severe TBI, that certain patients carrying risk for increased ICP such as those who are comatose (GCS <8) or those who have abnormal findings in the admission head CT scan (Le Roux, 2016) should be monitored for ICP changes. Although it is of utmost importance to manage ICP elevation in critical patients with neurosurgical conditions, ICP measurement is best done with invasive procedures such as ventriculostomy and intraparenchymal micro-transducers, which have their associated risks and procedural problems complicating their use in a busy ED (Robba, 2018).

Evaluation of ONSD has been used as an alternative tool to determine elevated ICP since the former is directly proportional to intracranial pressure increase (Seyedhosseini, Aghili, Vahidi, & Shirani, 2019). Detecting a raised intracranial pressure using ONSD, to determine the prognosis of patients with TBI, and to determine its relationship with other non-invasive, simple tools (transorbital USG, CT, or MRI) with a reasonable level of diagnostic accuracy are of great importance, especially for ED physicians working with a great burden of overcrowded EDs, whose aim is to determine whether a patient has a current critical condition or will be in critical condition during the course (Lee et al., 2020). Sönmez et al. reported that ONSD represents a powerful prognostic tool to predict disorientation in ED (Table) (Sonmez et al., 2019).

Traditionally, elevated ICP is represented in brain CT performed for TBI as cisternal compression, sulcal effacement, vertical size changes, midline shift of at least 3 mm together with a mass effect, transtentorial herniation, and altered gray/white matter ratio (Ozsarac et al., 2018); however, ONSD measurement (on admission or later in the course) with CT or bedside ocular US is a very simple method compared with CT. The rationale for ONSD evaluation is to prevent secondary injuries in TBI (Lee et al., 2020).

The scientific basis for using ONSD is the finding of increased TBI severity with increasing ONSD levels, which in turn determines a poor prognosis (Bekerman, Sigal, Kimiagar, Ben Ely, & Vaiman, 2016; Das, Shetty, & Sen, 2017). ONSD measurement is of particular importance among patients who carry a risk of undergoing a neurosurgical intervention unless invasive intracranial monitoring is carried out. The mechanism of ONSD enlargement involves a shift of CSF into the optic nerve sheath when the intracranial compensatory reserve is exceeded, which suggests a linear positive correlation between ONSD and ICP (Sekhon et al., 2014). ONSD measurement and its correlation with ICP is of particular importance in EDs where rapid and accurate decision-making determines the prognosis of TBI patients.

Table. *Corelation of ONSD according to the lesion specific pathology*

	Right ONSD		Left ONSD		Mean ONSD	
	Mean ± SD	p	Mean ± SD	p	Mean ± SD	p
Herniation						
Absent	7,62 ± 0,96	**0,024**	8,06 ± 5,59	0,095	7,84 ± 2,91	0,060
Present	8 ± 0,61		7,91 ± 0,6		7,95 ± 0,58	
Fracture						
Absent	7,68 ± 0,83	0,409	8,25 ± 6,37	0,606	7,96 ± 3,26	0,534
Present	7,64 ± 1,12		7,62 ± 1,05		7,63 ± 1,03	
Pneumocephalus						
Absent	7,67 ± 0,94	0,842	8,05 ± 5,4	0,287	7,86 ± 2,81	0,454
Present	7,68 ± 0,82		7,9 ± 0,9		7,79 ± 0,82	
Contusion						
Absent	7,7 ± 0,94	0,483	8,13 ± 5,79	0,998	7,92 ± 3	0,649
Present	7,53 ± 0,89		7,63 ± 0,94		7,58 ± 0,88	
SAH						
Absent	7,54 ± 0,9	**0,028**	7,55 ± 0,89	0,050	7,55 ± 0,87	**0,026**
Present	7,9 ± 0,96		8,93 ± 8,71		8,42 ± 4,41	
SDH						
Absent	7,63 ± 0,97	0,262	8,11 ± 5,92	0,334	7,87 ± 3,07	0,312
Present	7,79 ± 0,78		7,77 ± 0,71		7,78 ± 0,72	
EDH						
Absent	7,64 ± 0,94	0,120	8,03 ± 5,43	0,021	7,84 ± 2,82	0,061
Present	7,96 ± 0,81		8,16 ± 0,87		8,06 ± 0,83	
IPH						
Absent	7,62 ± 0,95	0,185	8,09 ± 5,92	0,073	7,86 ± 3,06	0,121
Present	7,82 ± 0,87		7,86 ± 0,84		7,84 ± 0,83	

Conclusions and Future Directions

The initial emergency care of TBI patients is composed of quick and targeted triage, rapid diagnosis of the intracranial pressure increase and disorientation of these patients. The reader of this book should be aware of that invasive monitoring is the gold standart of raised intracranial pressure but it is not feasible and possible in an overcrowded ED so, with the knowledge in mind that a variety of several factors affect both short- and long-term outcomes of patients with TBI, utilization of available resources, especially the point-care diagnostic and therapeutic strategies like bedside ultrasonograpy should be incorporated into the guidelines.

Applications to Other Areas of Neuroscience

In this chapter we have reviewed the prognostic effect of optic nerve sheath diameter measurement in patients who are admitted to emergency department with traumatic brain injury. We also interlink the role of optic nerve sheath diameter at detecting disorientation of patient quickly and hasten the timely intervention especially in patients who carry a risk of undergoing a neurosurgical intervention in the golden hour of these patients.

The interconnection between optic nerve sheath diameter measurement and intracranial pressure increase have been studied in many other intracranial pathologies. These include stroke, hyponatremia and cenral nervous system infections. The common point of all of them is that ONSD measurement is really a good prognostic mean in this patient group and for ESs, preventing secondary injuries is common and targeted outcome for all neurological acute admissions.

Key Facts of Optic Nerve Sheath Diameter

- Optic nerve is a part of the central nervous system, it protrudes into the orbita in the process of embryogenesis, with a free passage of the cerebrospinal fluid.
- Optic nerve sheath diameter can be measured via ocular ultrasonography or brain computed tomography or mangetic resonans imaging.
- After traumatic brain injury, increasing of intracranial pressure should be suspected especially in emergency department and an increase in intracranial pressure correlates with prognosis.
- Measurement of optic nerve sheath diameter at regular intervals can detect disorientation of patient quickly and hasten the timely intervention especially in patients who carry a risk of undergoing a neurosurgical intervention.
- Measurement of ONSD is promising in the medical world where patient follow-up is becoming popular with minimally invasive intervention.

Mini-Dictionary of Terms

- ONS: A nerve extansion of central nervous system into the orbita
- Intracranial pressure: A combination pressure of intracranial vessels, fluids and brain tissue
- Traumatic Brain Injury: A damage to the brain by external forces which can be blunt or penetrating and disrupts the normal brain function
- Cerebral edema: An excess accumulation of fluid (edema) in the intracellular or extracellular spaces of the brain.
- Subarachnoid space: The interval between the arachnoid membrane and the pia mater which communicates with cerebrospinal fluid as well as branches of the arteries and veins of the brain.

Summary Points

- According to the patient’s clinical status, traumatic brain injuries can be categorized as mild, moderate and severe. Neurological vital signs are pivotal in evaluating the patients’ severity.
- The major concern for emergency specialists is identifiying the patients with a moderate or high risk of neurosurgical intervention requirement.
- Since the time patients spend in the emergency department is the most important part of the intervention, it can be expressed as golden hour.
- Avoidance of secondary injury and providing a promising prognosis in traumatic brain injury patients, a strict observation can be done via optic nerve sheath diameter measurement especially in emergency department.
- Practical management of intracranial pressure increase should be directed according to the evidence-based recommendation levels in guidelines in a continuum manner.

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